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THE SENSORY ORGANS—SUGGESTIONS WITH A VIEW TO GENERALIZATION.[1]

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PERHAPS in the whole range of physiological and anatomical studies, no subject is invested with a deeper interest than that of the sensory organs. It is by means of them that we first become aware of our own existence; it is by means of them, in other words, that consciousness is first awakened in us, and it is through them that we subsequently continue our acquaintance with the outer world. It would be of great importance, were it possible, to arrive at some general conclusion regarding their morphology—some general view regarding the essential elements or the essential conditions of their structure. Judging from our knowledge at present it may seem that an attempt in this direction would be fruitless. Notwithstanding there are several prime facts which do not seem to have attracted the general attention which their importance deserves, and these when placed in their proper relations may give a new character to the subject, and perhaps open new avenues for investigation.

It will be interesting, therefore, to hastily review what is known regarding the *constant* elements of the various sensory organs. Under this head, of course, it will be unnecessary to consider the more or less mechanical arrangements by which force is conducted, and we will adhere, therefore, to that part of the literature only which treats of the ultimate structures by which impressions appear to be received.

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[1] Read before the Alumni Society of the Auxiliary Department of the University of Pennsylvania, March 29, 1878.

It will be found most expedient to commence with the *organ of hearing*.

Here the percipient structure is either situated in, or constituted by, the epithelium of the maculæ acusticæ of the ampullæ and saccules, and by Corti's organ. Concerning *this* there can be no doubt, and were we to analyze the subject no farther, it would be sufficient for our purpose. The epithelium of the maculæ acusticæ, as we know, is made up of several kinds of cells. Prominent among these is one bearing a hair-like structure on its peripheral end, and possessed of central out-runners or processes. Now regarding the distribution of nerve-fibres to these acoustic spots we may hold the following views: either that the nerves end in plexuses and loops *in* or immediately *beneath* the epithelium, or that they are directly continuous with either the cylindrical, the stellate or the hair-bearing cells. Almost any one of these suppositions would suffice for the main points of the generalization I have in mind, but when we turn to the literature bearing immediately on this point, we learn that the constant or essential element of the maculæ acusticæ, and in fact of the organ of hearing, appears to be a cell bearing a central and a peripheral process. This cell is constant throughout vertebrates and, as far as known, throughout invertebrates. The entire literature makes it also more than probable that these cells are directly continuous with nerves. Thus, Max Schultze already in 1858 (Muller's Archiv), in speaking of the ultimate nerve termination in the ear of the petromyzon, ray, pike, etc., advanced strong grounds in support of this view. Deiters, in 1860 (M. A.), described the hair-cells of birds, and considered their connection with nerves probable, while in 1862 (*Ibid.*) he described the hair-cells of amphibians, and in the "lagena" believed them to be directly continuous with nerves. About this time, also, F. E. Schulze claimed to have seen the direct transition of nerve fibres into the auditory hairs of young sea gudgeons. In 1867, Hasse (Zeitsch. d. Wissensch. Zoölogie, Bd. xvii) described the hair-cells of birds, and said that he clearly made out the entrance of the nerve-fibres into them. He said that he frequently traced the central processes of the cells for long distances in the course of the nerve-fibres, and *vice versa*, he traced the nerve-fibres in the direction of the central processes. Odenius, 1867 (A. f. M. A.), advocates for man the same thing. He says, that all comparative researches point to that conclusion; that the fibres of the auditory nerve do not end in loops, that they do not become continuous with the blunt-ended cylindrical nor the stellate cells. The only remaining element is, therefore, the hair-cell, and this in every way supports the view of its nervous connection. It not only becomes stained with osmic acid (Waldeyer, Stricker's Hdb.), similar to nerve fibres, but its central process presents the same appearance as the latter. In 1868, Hasse (Z. f. W. Z., Bd. xviii) investigated the ear of the frog, and strongly expressed the same view as maintained by the previously mentioned authorities; in fact, in one instance he believes to have really seen the nerve terminating in the hair-cell (stäbchenzelle), but does not lay too much stress upon it. Waldeyer, 1868 (Stricker's Hdb.), claims the nervous continuity of the inner hair-cells of Corti's organ as a positive fact. He says, "the inner radial (nerve) fibres pass, as I have often been able to prove, directly through the granular layer and terminate in the pointed ends of the inner hair-cells." Gottstein, 1872 (A. f. M. A.), like Waldeyer, says, that the inner radial nerve-fibres enter the inner row of hair-cells, while the outer are supplied by fibres stretching directly across the tunnel formed by Corti's arch. Ladowsky, 1876 (A. f. M. A.), expresses emphatically the same conclusions maintained by Gottstein. He asserts notwithstanding the purely negative results of Nuel (A. f. M. A. viii), the nervous connection of the hair-cells strenuously as follows: "I assert, along with Boetcher, that the connection between nerves and cells can nowhere be demonstrated so clearly as in the cochlea . . . . . Boetcher says, that he could, with some animals, as the hedgehog, find the connection of the nerves with the end-cells in almost every section."

The Organ of Smell.—This, when analyzed, appears likewise to consist of a cell with a central and a peripheral process. The outline of the literature is as follows:

In 1857, Ecker described the epithelium of the olfactory region (Z. f. W. Z. Bd. viii), but did not claim any nervous connection with cells. Later investigators, however, J. L. Clark and Max Schulze, strongly advocated the view of the direct nervous continuity of the so-called "olfactory" cells. Clark, 1862 (Z. f. W. Z. Bd. xi), traced the nerves into a fine sub-epithelial plexus, and thence believed them to become continuous with the central processes of these cells. Max Schultze, 1863, (Abh'dl'g. d.

Naturges. zü Halle, vii), described the olfactory cells of fishes, amphibians, birds and mammals, and strongly argued for their direct continuity with nerves. His theory rests on the complete chemical and morphological analogy between the central ends of the olfactory cells and the nerve fibrillæ. Prof. Babuchin, 1868 (Stricker's Histology), says that he possesses a chloride of gold preparation from a tortoise, in which can be observed the immediate passage of the nerve fibrillæ into the epithelial layer, "where they can be followed into the nuclei of the olfactory cells." He says, "this might raise M. Schultze's hypothesis to an actual fact if we possessed in the chloride of gold a substance which stained only nervous elements, and if this re-agent were not so very uncertain in its action." Von Brunn, 1875 (A. f. M. A. xii), describes, in addition to the epithelial and olfactory cells described by Clark and Schultze, a homogeneous membrane covering the olfactory region of mammals, and which is pierced by the peripheral processes of the olfactory cells. This arrangement would seem to exclude the epithelial cells from immediate contact with any substance inhaled into the nostril, and confine such contact entirely to the peripheral ends of the olfactory cells. This would go very far to establish the fact that the olfactory cell is the essential or percipient structure of the organ of smell. At any rate, it is a cell peculiar to the olfactory region, is *constant* throughout vertebrates, and like the corresponding structure in the organ of hearing, the weight of evidence is in favor of its direct nervous continuity.

The Organ of Taste.—Here we meet with a peculiar difficulty at the outset, and one to which the consideration of other organs is not subject. It is at first a matter of doubt as to what structure really constitutes the organ of taste. From the literature of the subject, however, I think it may be fairly attributed to the so-called taste-buds, as is almost unanimously done by the investigators of these organs. The taste-buds are distributed most thickly where the sense of taste is most acute, and less thickly on parts of the tongue where the sense of taste, *per se*, is less but where the *general* sensibility is greatest, as the tip and anterior part of the dorsum. What gives the most ground for doubt regarding their gustatory function, is that Verson has found them on the lower surface of the epiglottis and Krause on the dorsum of the same. The latter, however, does not consider this an objection to their being concerned in the sense of taste, while C. Davis (1877 A. f. M. A.), who describes these organs as existing in the upper parts of the larynx, says that whatever we consider as their function we must regard them as terminal organs of the glossopharyngeal nerve. He says that Vingtschau and Hönigschmied have given experimental evidence that the buds at the dorsum of the tongue are terminal organs of the glossopharyngeal, though he neither says in what the experimental evidence consisted, nor gives any references where it might be found. Leaving you to form your own views, I will briefly pass over the pertinent literature of these organs. They have been found in fishes, amphibians and mammals. Waller appears to have been the first to investigate the epithelium of the fungiform papillæ of the frog, while Leydig first described the "taste-disks" of fishes, and was disposed to consider them as tactile organs (1851, Z. f. W. Z. Bd iii, also 1857, Lehrb. d. Hist.). Billroth, 1858 (M. A.), and Hoyer, 1859 (M. A.), both described the peculiar epithelium of the taste-papillæ of the frog, and while the former thought a connection between it and nerve-fibres probable, the latter described the nerves as terminating bluntly beneath it. Axel Key, however, 1861 (M. A.), described the same structure and pictured the nerve-fibres as directly entering certain cells, which are designated by the term "taste-cells." His results were attacked by Hartman, 1863 (M. A.), who, although he could assign no definite termination to the nerves himself, supposed them to end in plexuses beneath the cells. Beale, however, 1865 (Phil. Transactions), strongly supported Axel Key in the essential points. He showed that Hartman had destroyed the finer structures by his method of examination. Speaking of the nervous connection of these cells, he says: "In many specimens I have seen, and most distinctly the delicate network of fibres (in the body of the papilla) continuous with the fine nerve-fibres in the summit of the papilla, and I have demonstrated the continuity of these fine fibres with the matter of which the outer part of these peculiar cells consists. . . . . Upon the whole, I am justified in the inference that there is a structural continuity between the matter which intervenes between the masses of germinal matter at the summit of the papilla and the nerve-fibres in its axis, and I consider that an impression produced upon the surface of these peculiar cells may be conducted by *continuity of* *tissue* to the bundle of nerve-fibres in the body of the papilla." In 1869 (Quart. Journal Micr. Science), Beale reiterated the same statement. In 1867, Engelman (A. f. M. A., iv) investigated the taste epithelium of the frog, and in the essential points of a cell with peripheral and central processes, and of the last being continuous with nerve-fibre, he agrees with Axel Key. Dr. Maddock, 1869 (Monthly Microscop. Journal), also investigated the same structure. He describes the taste-cells or rod-cells, as he calls them, and strongly supports the view of their direct nervous continuity. He says that the sensory nerves of taste do not terminate in free ends, " but in terminal organs consisting of nerve matter surrounding a germinal mass or nucleus; in fact," says he, " I regard them to the plexus of nerves beneath the papilla in the same relation as the retinal rods to the optic nerve."

In 1863 (Z. f. W. Z., Bd. xii), F. E. Schulze redescribed the taste disks of fishes and laid great stress on the fact that these structures are found in greatest number just where the glossopharyngeal nerve is most thickly distributed. They are found on the gums, the tongue rudiment, the inner side of the gill arches and the barbels, but also in lesser numbers on the lips and skin of the head and body. These last, as Schulze supposes, are probably for the purpose of perceiving at some distance substances dissolved in the water. He describes the taste-disk as consisting essentially of two kinds of cells, one being merely a supporting structure, and the other the percipient structure. The latter bears a central and peripheral process. In 1867, the same observer (A. f. M. A. iii, p. 152), states that the peripheral process bears a small hair as it does in mammals. In 1870 (A. f. M. A.), he also described the taste-discs of the tadpole, and remarked their close resemblance to those of fishes, which might almost have been predicted.

In 1868, Schwalbe (A. f. M. A. iv,) and Loven (Ibid.) described almost simultaneously and independently the taste-buds of mammals. Their descriptions agreed in all essential points; namely, in there being two kinds of cells, one having the value of a protective or supporting structure, and another which had a central and peripheral process and which was probably continuous with nerve-fibre, which in its chemical reaction it resembles (Engleman in Strickers' Hdb.). Subsequent investigators have merely corroborated the results of the preceding. Thus, von

Wysen, about 1870 (A. f. M. A. vi); von Ajtai in 1872 (A. f. M. A. vii); Hönigschmied in 1873 (Z. f. W. Z. xxii), who also noted the occurrence of taste-buds on the *free* or *upper* surface of circumvallate papillæ, though their presence here was not constant and they were generally smaller than those found on the sides. He says, also, that there can hardly be any doubt regarding the continuity of the taste-cells with nerves. In chloride of gold preparations from the cat he traced the nerves directly into the buds, and what is worthy of remark, the cover cells were *not* stained by chloride of gold, while the taste-cells *were*.

Before proceeding any farther, it will be necessary for the correct understanding of the view I wish to present, to consider some organs not possessed by man.

In fishes and amphibians we find a set of organs whose sensory character was first claimed by Leydig in 1850 (M. A). I refer to the so-called "mucous canals." In 1861, F. E. Schulze (*Ibid.*) re-described these organs as containing small cellular elevations, from which arise a number of stiff parallel hairs, which reminded both him and Leydig of the auditory hairs. A profile view of the typical structure, according to Schulze, reveals a hyaline cylinder generally much longer than the hairs, which it encloses and to which it allows free access of water. In speaking of the relation which the nerve fibres bear to the cellular elevations, he says: "In the lower layer I see round cells . . . . . These I take to be connective tissue cells. Between these last we see in fishes of a certain degree of development (15 mm. and over), sharply contoured nerve fibres which are given off from the nerves approaching the elevation. After they have passed between these cells they terminate by means of a "conical narrowing" in the above mentioned hairs. This is most readily seen by fixing the eye upon a single hair and then following the inward continuation of the same. In so doing we recognize as the base of the hair a conical body which protrudes over the epithelial surface. . . . This little ten-pin-shaped body (Kegel) we again recognize as the narrowing of a nerve fibre lying between the epithelial cells. . . . . ." In 1870 (A. f. M. A.), F. E. Schulze re-investigated these organs, and made some important additional statements. What he had previously described as a ten-pin-shaped narrowing of the nerve fibre into which the hair is inserted he now describes as a nucleated cell; *i. e.* he now describes as the ultimate sensory apparatus in the mucous canals or side organs of fishes and amphibians certain nucleated cells bearing hairs and connected with nerve fibres. His conclusion regarding the function of these structures is as follows: That the side organs " represent a sensory apparatus especially adapted to presence in water, and for the purpose of appreciating mass movements of the surrounding medium against the body of the fish or of this against it, and also to perceive coarse waves which are promulgated by the water and which have longer periods of vibration than those appreciated by the organ of hearing."

Transitional forms between such of the side organs as have large, hyaline cylinders and which stand out directly from the body of the fish, and the completely covered mucous canal, are present. Some are described in which the cylinder is small, rudimentary or absolutely wanting. Others still which are situated in a groove or depression of the surrounding skin, and some in which the edges of the groove overlap and thus form the transition to the covered mucous canal. The significance of this is unmistakable. In 1868, Franz Boll (A. f. M. A. iv) investigated the mucous ampullæ of the snout of the shark and the *Torpedo marmorata*, and described and pictured as the essential and percipient structures of these organs cells with central and peripheral processes, and argued for the nervous continuity of the same. Langerhans, 1873 (A. f. M. A. ix), described the side organs (or organs of a sixth sense as Leydig calls them) of the larva of Salamandra maculosa. His results agree in every particular with those of F. E. Schulze. Malbranc, 1876 (Z. f. W. Z. xxvi), also supports the results of F. E. Schulze and Langerhans completely. Previously the side organs had been described only in *larval* amphibians, but Malbranc also found them in the adult forms of Proteus, Siredon, *Triton cristatus* and *tæniatus*.

That the essential or percipient structure of the side organs can be expressed in the same terms as the auditory, olfactory and taste-cells, seems indisputable, nor can we fail to appreciate the significance of this fact. Indeed, already in 1862 Max Schultze expressed views regarding the identity of the nerve terminations in the organs of hearing, smell and taste; and in speaking of the common sensation of fishes, he says (Sitzbericht d. Niedl'd. Ges. zu Bonn. 1862), " Here there are places in the skin where the nerve-cells not only protrude themselves into the epidermis, but also carry hairs which extend beyond the epithelial surface, as in the ear. They serve probably as tactile organs of the most delicate character in order to take note of movements of the water which would not be appreciated by ordinary organs of touch."

In man the character of the medium in which he lives and the dryness of the epithelium, would seem to forbid such a structure, yet it becomes a very interesting question whether in mammals in which the necessary external conditions are present such a structure reappears. Indeed, our interest is perhaps augmented when we find that Camper, about 1822, discovered innumerable openings on the lower jaw of the whale, which were like the mucous canals of the pike. Concerning their structure and even their presence in other Cetaceans nothing is known.

There are certain great facts of embryology which might almost lead us to suspect from an "*a priori*" point of view some bond of union between sensory organs. In the first place, the nerve epithelium of the ear, the olfactory region and the taste-buds, are developed from one and the same layer, namely, the epiblast of the embryo. Again this layer is the same as that from which the central nervous system is developed, and this fact alone would naturally lead us to look for the ultimate sensory apparatus in the *epithelium.* These organs being developed in the same layer, we might expect to find some morphological connection or relation between them. The ear, as we know, is formed by an inflexion of the epiblast, while the nasal and oral cavities are lined by the same layer. Therefore, if, as we have seen, there are sensory cells in the epithelium covering the body, the cavities formed by the inflexion of this epithelium would contain these sensory cells.

For the ear, even additional evidence is furnished by the Savian vesicles of the torpedo. These are closed fibrous capsules, containing an interior granular substance, and supplied by a nerve twig. They are arranged in linear series bordering the anterior part of the mouth and nostrils, and extending over the surface of the fore part of the electrical organs (Owen, Comp. Anat.; and Boll M. A. 1875). Max Schultze was the first to investigate the histology of these organs. He tells us that they contain an epithelium bearing stiff, non-vibratile hairs, and he expresses the opinion that the nerves bear the same relation to it as in the ear, nasal m. m. etc. Boll (M. A. 1875) re-investigated the Savian vesicles and described them more minutely. He corroborated the general statements of Max Schultze with regard to the hair-bearing epithelium, stating that the hairs are so very perishable that they can only be observed in fresh preparations. He finds on the floor of the vesicle three small eminences lying in the direction of the fibrous attachment, the middle one being the larger. These are constituted by cylindrical epithelial cells and the perceptive cells, while the rest of the vesicle is lined by a flat epithelium. The nerves are distributed *exclusively* to the *eminences*, and are, as Boll thinks, probably continuous with the perceptive cells. These bear peripheral and central processes.

Regarding these organs Max Schultze (Abh'dl'g. d. N. ges. zu Halle. 1863) makes the following interesting remarks: "As they are closed vesicles and lie somewhat deeply hidden, we can look upon them as the transitional forms between feel-hairs ending freely in the water and which are possessed by fishes and naked amphibians, and the nerve-hairs of the ampullæ of the organ of hearing. In this last, the arrangement of the nerve-endings for the perception of sound waves from the endolymph, is evidently so similar to the structure in the Savian vesicle, that the question might arise whether the latter belongs to the sound perceiving organs. As the electric ray possesses very well-developed organs of hearing in the shape of otolith saccules and semicircular canals, there are no grounds for ascribing yet another organ of hearing to it. Therefore we adhere to the supposition that the Savian vesicles are a special modification of the organs of common sensation. . . ." Further on, he says that they probably appreciate coarse waves or vibrations in the water.

A very significant fact, and which probably brings the side organs or mucous canals, the Savian vesicles and organ of hearing into the same category, is the following: The Savian vesicles are supplied by the *fifth* pair of nerves, while the mucous canals or side organs are supplied by the lateral nerves, which again are *made up largely of the fifth*, in some fishes almost entirely; and a most remarkable fact, but one which is entirely explainable by embryological data, is, that in one fish, the skate (Owen, Comp. Anat.), the auditory nerve is apparently a *primary branch of the fifth!*

Now, while bearing the facts with regard to the sensory organs in the epithelium of fishes and amphibians in mind, let us see what is known regarding sensory structures in the epithelium of mammals. At once the well-known results of Connheim (Virchow's Archiv xxxviii, 1867) and Hoyer (M. A. 1866, also A. f. M. A. ix 1873) with regard to the nerves of the cornea occur to us, which prove that the nerves really enter the epithelium. Besides this, Langerhans (Virchow's Arch. xliv, 1868), demonstrated in man the entrance of nerves into the epithelium covering the body. He describes the nerves as entering the rete mucosum and then passing upward between the epithelial cells. He describes also peculiar stellate bodies which he thinks are very probably continuous with the nerves, on account of their chemical reaction. Podocopaew (A. f. M. A. v. 1869) confirms the results of Langerhans for the rabbit in all essential points. Eberth (A. f. M. A. 1870) likewise supports the investigations of Langerhans in the important particulars, and believes that no terminal network exists, but that the nerves end free in the epithelium. Chrschtschonowic (Sitzbericht. d. Wiener Acad., Feb., 1871) says that the nerves enter the vaginal epithelium and there form plexuses. Elin (A. f. M. A. vii, 1871) says that the nerves enter the epithelium of the mucous membrane of the mouth and join cells "in the upper part of the rete mucosum" fibres, also passing to the upper part of the epithelium. Eimer (A. f. M. A. viii, 1872) described the nerves as entering the epithelium of the teat of the cow, and believes them to be continuous with the "Langerhansian bodies." Perhaps more interesting than all, however, are the results of Eimer (*Ibid.* vii, 1871) with regard to the snout of the mole. This investigator describes the nerves as entering the epithelium covering the snout and passing upwards. The epithelial cells immediately above the entrance of the nerves are arranged in a circular manner, so as to present somewhat the form of a cylinder, thus producing a *specialized* structure. Eimer tells us that whenever a nerve-fibre passes one of these cells, it presents a bulbous enlargement or swelling, and finally terminates by such a swelling in one of the cells.

Now, whether the nerves end free, end in plexuses, in the Langerhansian bodies or the cells of Eimer, of one thing we are certain, and that is that the ultimate sensory structure is *in the epithelium*, a conclusion which, it is needless to say might have been predicted on "*a priori*" ground.

I think it well now to present the interesting results of Meckel

(A. f. M. A. xii), as at least a possible, if not a probable method, of explaining the touch-bodies; *i. e.*, the corpuscles of Krause, of Meisner and Wagner and the Pacinian bodies. Koelliker tells us that they are all probably modifications of one and the same thing, as intermediate forms exist all over the body. Now Meckel describes cells as existing in birds and mammals into which he directly traces nerve-fibres. He designates them as "touch-cells" and describes their transition into touch bodies. The touch-cells are situated ordinarily *beneath* the epithelium, but in the bill of the pigeon they present every transitional stage between cells entirely buried in the sub-epithelial tissue, cells partially extending into the epithelium, and cells entirely enclosed by the epithelium. Again, in the snout of the hog the "touch-cells" are *all* in the epithelium, though in its lowest layers. They are larger than nerve-cells generally, and frequently two or more become joined so as to form twin cells or a more complex arrangement. These last are found *beneath* the epithelium. Then he also describes structures made up of a larger number of cells, but in which the nerve-fibre still supplies each individual cell. Then he describes others which are still more complex and in which the separation into cellular elements is still less apparent. All the complex forms are *beneath* the epithelium, only the single cell is found in the latter.

If the results of Meckel are *correct*, we have a link between the sensory structures of the epithelium and the touch-bodies, and the latter might be looked upon as epithelial structures in reality, but which have become displaced in the progress of development. The legitimacy of such an inference, however, would be rendered highly doubtful by the existence of the Pacinian corpuscle in the mesentery of the cat. To these last structures Arndt (Virch. A. lxv, 1875) ascribes a very peculiar significance, but which is hardly satisfactory. From observations on fœtal cats he comes to the conclusion that the Pacinian corpuscle is an outgrowth of the vascular system of the mesentery.

Let us now turn our attention to a field that has been thus far neglected; namely, the *organ of sight.* The retina, though not developed from the epithelial layer of the embryo, is yet produced by an outward growth of another portion of the same layer. To this, however, I think we should not attach too much importance.

In all the retinæ of vertebrates two elements among others appear to be constant, namely, the layer of rods and cones and one corresponding to the layer of external granules. Each rod and each cone is thus connected with a cell element, and certainly it requires no great stretch of the imagination to see here a structure corresponding to a hair-cell. We have a cell with a central and peripheral process which last bears an apparatus to receive the immediate impression of force. Besides evidence by no means ends here. In those invertebrates whose eyes approach and even exceed in their complexity those of vertebrates, as the gastropods and cephalopods, the same elements remain constant, namely, the rods with their cells (Schultze, A. f. M. A. v, 1869), (Babuchin, Würzburg Verh'dlg, 1865) (Hensen Z. f. W. Z. xv, 1865).

We must remember also that in the eyes of molluscs the relation of the rods to the eye is exactly the reverse of that in vertebrates; namely, they point directly forwards and constitute the *innermost* layer of the retina, while in vertebrates they point directly backwards and constitute the *outermost* layer. This fact assumes great significance when we learn what is known concerning the development of the eyes of molluscs. Hensen says (Z. f. W. Z. xv., 1865), that the eyes of cephalopods probably originate in the same manner as the ear and nose of vertebrates, *i. e.*, by an inflexion of the epithelial layer. In the nautilus, he says, it is evidently the case, while for the gastropods this has *actually been observed* in a pulmonate snail of the Phillipines, by C. Semper[1] (quoted by Hensen).

When we are told by Boll (A. f. M. A. v, 1869, supplement), that the epithelium of molluscs everywhere contains hair-cells continuous with nerves, it would seem to place the morphological value of the rods and cells in these animals beyond a doubt. Boll describes what he calls the "neuro-epithelium." He pictures *stiff, non-vibratile* hairs, distinct from vibrating ciliæ, and surmounting elongated nucleated cells. They occur all over the surface of gastropods and cephalopods, being more thickly situated in parts used for apprehension or contact, as the arms of the cuttle-fish and the edges of the foot of the snail. Flemming (Ibid. v, 1869 and vi, 1870) corroborates Boll's statements in the main points, though he differs from him in the detailed description of the hairs.

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[1] Semper has written a separate paper on molluscan eyes, which I could not obtain.

Boll also, although he determined the direct nervous continuity of the hair-cells in the ears of these animals, did not establish the nervous connection of the hair-cells in the epithelium. Flemming described long central outrunners, which can be drawn out from the sub-epithelial tissue to a comparatively great length, and which become more or less varicose in preparations treated with potassium bichromate and osmic acid. He also describes the sensory cells of pulmonate snails, but in these the hairs do not reach above the surface of the epithelium, apparently a modification to suit external conditions.

Judging from the above, we have, to say the least, good grounds for including the percipient structure of the organ of sight in the same generalization as that of the other sensory organs. As regards the other layers of the retina, may they not be simply of ganglionic value? The comparative simplicity of the retina of molluscs seems, in cephalopods, to be counterbalanced by the existence of a ganglion just before the optic nerve enters the eye. Again, the ganglionic character of the olfactory lobes may be of equal value. Indeed, this comparison might assume importance when we remember that both the olfactory lobe and the retina are processes of the cranial vesicles.

Conclusion.—In casting a last glance at the sensory organs they seem to arrange themselves more or less readily into groups. Thus, the side organs or mucous canals, the Savian vesicles and the organ of hearing, seem to constitute a sub-division by themselves. The organs of taste and smell seem to constitute another, while the eye seems to occupy a third sub-division alone. With regard to other sensory structures it would be hazardous to make any suggestions.

On the ground of certain principles that I have expressed, and of others even far more general, we may be led to suspect from the very beginning the common genesis of sensory organs; and it was a sincere conviction in the truth of such principles that led me to read the literature bearing immediately upon the subject, and to learn in how far such an opinion is supported by fact. How much it is supported by the results of the investigators which I have adduced, and the possible relations I have pointed out, I will leave you to judge.

[Note.—The literature referred to in this paper is that only which pertains directly to the questions in point. One or two papers I have been unable to obtain and have quoted them from others. I have knowingly omitted none that seemed important or the results of which seemed to contradict the general views suggested by the writer, with perhaps the single exception of the paper of C. B. Reichert (A. f. A. and Ph., 1871), who thinks that the early differentiation, in the embryo, of the epithelial layer and the central nervous system destroys all probability of the nerve endings being in the epithelium. How much his opinion is supported by fact, the more recent literature as adduced will enable you to judge. He rejects, in consequence, altogether the nerve-termination in the organ of hearing, as held by most observers, and even denies that the nerves pass through the openings in the zona perforata! a fact which every investigator with whom I am familiar admits and which I have myself witnessed. Reichert is the only one to my knowledge who so radically denies the results of the other investigators. To me the general agreement among so many observers, in such varied fields of research, seems to point unmistakably to some *one underlying truth.*]

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PLANTS USED BY THE INDIANS OF THE UNITED STATES.

BY DR. EDWARD PALMER.[1]

The first paper upon this subject by the writer was published in the Report of the Department of Agriculture for 1870. The present paper will embrace all the additional matter that has since come under his observation.

Fruits and Nuts.—*Juniperus pachyphlœa* Torr., one of the finest ornamental Junipers, its wood being excellent for cabinet work; height about forty feet, and diameter from two to three feet. Abundant in Arizona. Its fruit, a staple article of food among the Indians, is sweet, having but little of the juniper taste. As soon as ripe the Indians commence to eat the nuts raw, and to lay up great quantities for winter use. They are then ground fine and made into bread.

J. Californica, a dwarf but showy evergreen. Southern Californian Indians consume immense quantities of the fruit

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[1] The writer wishes to acknowledge his obligations to Prof. Asa Gray; Mr. Sereno Watson, of Cambridge, Mass.; Dr. C. C. Parry, Davenport, Iowa, and Dr. George Vasey, Department of Agriculture, for kindly determining the species.